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DPD-5453-61
6 September 1961

Information Fidelity Incorporated
Las Vegas, Nevada

Attention: Mr. Herbert Miller

Subject : Expanded AR Research Program, Including Technical
Supervision and Operation of Government-Owned
INS AR Model Range Facilities

Gentlemen:

This will confirm Headquarters discussions held on September 5 and 6, 1961, and constitute authority for you to proceed on an expanded AR Research Program, in general conformance with your AR Research Program proposal dated August 11, 1961, utilizing for this purpose the facilities of a Government-owned AR Model Range to be established in Indian Springs. This expanded work scope includes technical supervision during establishment of and installation of equipment in the AR Model Range facility at INS, as well as subsequent maintenance and operation thereof through June 30, 1962.

An amendment will be forthcoming to Contract No. CC-28441 covering this expanded effort and increasing the estimated contract cost for the period ending June 30, 1962, by an amount of \$168,324.00, and increasing the fixed fee by an amount of \$9,451.00. This fee increase is predicated upon your having in your employ and beneficially utilized for operation of the AR Model Range, the following level of personnel effort through June 30, 1962:

- a. 22 man-months supervisory and/or electronic maintenance engineers.
- b. 24 man-months electronic and/or electro-mechanical technicians.

The above estimated cost of \$168,324.00 breaks down as follows:

1. Direct operating costs AR Model Range \$74,144.00. ✓
(including six man-months of a theoretical circuitry engineer, \$7,000.00, and equipment refinement costs estimated at \$15,000.00).

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2. Equipment fabrication costs \$44,000.00.
3. Equipment procurement \$39,180.00.
4. Model stand \$10,000.00.

INS site rehabilitation and construction costs, estimated at \$22,000.00, will be funded outside the present contract.

As per our discussions, a monthly report covering all work accomplished shall henceforth be submitted in duplicate to Headquarters.

The forthcoming amendment covering this expanded scope of work will contain a list of Government-furnished equipment with provision, however, that such equipment may be procured under this contract upon determined unavailability thereof direct from Government sources. Likewise, authorization is hereby given for your procurement of necessary Alfred equipment not to exceed \$12,000.00, such equipment having been determined as unavailable from Government sources.

There is hereby obligated to Contract No. CC-28441 an additional \$150,000.00, the balance remaining subject to availability of funds for this purpose.

Very truly yours,

Contracting Officer

Accepted:

Information Fidelity Inc

Pres.

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AR RESEARCH PROGRAM

August 11, 1961

The application of AR techniques to the present O configuration has been based upon both logical and intuitive deductions from an intensive measurement program. That there have been significant advances in the past six months (and particularly in the past four months), leading to important simplifications in fabrication and significant weight-saving, can probably be attributed almost equally to both types of deductions drawing heavily on our scientific training rather than to a precise knowledge of the details of the electromagnetic and material behavior phenomena involved. In view of the urgency of the program and the imminence of deadline dates when the I.F.I. group embarked upon full-time participation, such a course was necessary even though time consuming, due to the fact that we have been forced, at times, to proceed by trial and error rather than upon the solid base of knowledge derived from more fundamental experiments.

Generally speaking, our experimental program will be directed toward the objective of providing significantly more effective AR measures and techniques for follow-on items (i.e., #6 and for later items) of the O project and adaptable by retrofit to earlier items. It will have as a parallel objective, providing basic knowledge in the AR field for application, as appropriate, to the O project, as well as other vehicles. Thus, the program will encompass a careful study of (1) the backscatter and diffraction fields from objects at various aspects and polarizations of the incident field; and (2) the electrical, magnetic, and shape characteristics of the AR measures and techniques most effective in influencing these fields so as to reduce radar cross-sections of the objects being observed.

An airplane consists, basically, of an assemblage of cylinders, cones, truncated cones and flat plates. Thus, we plan to begin with experiments in which the fields are essentially parallel and perpendicular to the principle axes of such simple shapes and obtain data which will, among other results, permit mathematical analyses to be performed¹. Such experimental results and analyses will contribute importantly to the development of a sound base of knowledge of wave behavior and field characteristics from which it will be possible to proceed, again, by carefully designed and executed experiments, to the determination of the most effective AR measures and techniques applicable to simple and progressively more complex shapes.

¹For example, see King and Wu, "The Scattering of Waves", Harvard University Press, 1959; Kerr, "The Propagation of Short Radio Waves"; Vol. 13, M.I.T. Radiation Laboratory Series, McGraw-Hill, 1951.

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While it should be understood that it is not possible to define completely in advance the precise progression of the course of the experiments planned, as new data derived from the experiments to be performed and the analysis thereof may dictate exploration along unforeseen lines, the orientation of the planned research program to meet the parallel objectives noted above will be evident from the discussion which follows relative to the principal specific research areas which will be covered.

A. CHINES, SURFACE AND VOLUME TREATMENT

In the O configuration, plastic-skinned chines have been added to the substantially cylindrical, truncated conical and conical sections to enhance the AR capability. Until relatively recently, the chine embodiment contemplated the employment of metal "teeth" extending outward from the metal skin of the fuselage and nacelles, the use of full depth carbon-loaded honeycomb between the metal teeth and an appropriate resistive surface loading, all combined to provide a transition from full space to the metal skin and thus reduce broadside reflection from the areas thus treated. As a result of I.F.I. investigation, it was ascertained that a more effective AR treatment could be achieved if the metal teeth themselves, as well as the spaces between them, were to be covered by a "blanket" of resistance-loaded honeycomb, sandwiched between thin surface-loaded skins. While initial experiments on the employment of the blanket treatment were performed with material thicknesses equivalent to approximately 4 inches at full scale, this thickness was quickly reduced to 1 inch (i.e., 1/2 inch of additional honeycomb over that normally required for support of the plastic skin covering the chine) as progress was made (by trial and error experiments based on intuitive deductions) in appreciating the necessity for appropriately tapering the loading of both the volume and surface elements of the treatment, depending upon both the diameter and shape of the particular portion of the vehicle. That the "blanket" type chine resulted in a better AR transition to the metal sections thus treated was further demonstrated through the I.F.I. experiments which led to the elimination of the metal teeth (always considered a complex and costly fabrication problem) and the substitution therefor of simple bulkheads to support the chine structure. The efficacy of this treatment has now been demonstrated at all frequencies of interest.

It is now planned to pursue the path thus opened in the use of "blanket" treatment type chines by initially reverting back to simple shapes starting with the cylindrical. The so-called barrel section of the O configuration (i.e., roughly equivalent to that

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portion of the airplane fuselage extending from the wing forward to just aft of the cockpit) has been the closest approach to a simple shape with which we have had an opportunity to work. Utilizing this section, improvements in the effectiveness of the blanket treatment have been achieved. To the present, we have been able to reduce broadside cross-sections on this shape for polarization parallel to the axis to the values shown in Table I (reference 5ESB-74B), in which there is also tabulated the calculated cross-section for a metal cylinder without chines comparable dimensions (i.e., about 27 feet long) using the equation

TABLE I

Full Scale Frequency

Full Scale Cross-Section

74 mc/s
94.5
171 ± 19

Achieved
3.0 m²
2.2 m²
1.0 m²

Calculated Cylinder
38 m²
116 m²
203 m²

While it is thus evident that improvements of the order of 20 db have been achieved on a broad-band basis, the "barrel section" has not lent itself to the full exploration considered necessary before further advances can be expected. For example, the chine on the barrel section is not symmetrically located on the cylinder and, hence, does not lend itself readily to checks of experimental data against theory. As a consequence, we plan to begin our studies of the roles of surface and volume loading, as a function of object shape frequency and angle of wave incidence with symmetrically located chines of various depths on a cylindrical shape. This will be followed by studies of the various parameters for asymmetrically located chines and tapered chines; the former providing background for improving the fuselage treatment and the latter for the nacelle.

Similar studies, i.e., of surface and volume loading, frequency angle of wave incidence, polarization, etc., for a right circular cone and a right circular truncated cone to set the basis for understanding and improving respectively the nose and cockpit area, will next be undertaken. Here again, the shapes will be fitted with chines, initially symmetrically disposed and later asymmetrically. These studies will include full depth chines, as well as chines increasing linearly, or almost so, with longitudinal distance from the apex of the cone.

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B. WINGS AND FINS

Concurrently we will re-examine the work of previous investigations into flat plates, which led to the design of the wings and fins. We will then initiate a program of theory and experiment similar to that described for the chines looking toward further improvement and/or simplification in the AR performance in these areas.

C. WING ROOT JUNCTIONS

The understanding of the phenomenon involved in the so-called Miller effect is on very shaky ground. The Miller effect concerns the reduction of return due to a protuberance from a flat metal plane when the electric vector is in the plane of incidence and near grazing incidence. It has been discovered that the placing of relatively thick electric absorbers or considerably thinner magnetic absorbers on the plane in front of the protuberance is more effective than placing the same absorbers right on the protuberance.

Our only clue to an understanding of this phenomenon has come from some experiments carried out by Meyer (Germany) in which he found that the electric field strength near such an electric absorber, under similar conditions of incidence and polarization, dropped as the wave propagated along the absorber. The characteristic height at S-band was of the order of 10-15 cm. Such a reduced field strength could account for reduced reflection from any protuberance which has a vertical extent of as much as 10-15 cm.

We have extended our empirical experimental evidence to include thin magnetic absorbers and have found a quantitatively similar effect. However, neither our empirical nor fundamental understanding of the existing situation for magnetic absorbers has been developed as far as our inadequate knowledge of the situation for electric absorbers. We plan to conduct experiments somewhat analogous to those employed by Meyer to further our fundamental knowledge of these effects. These tests will include evaluation of the relative effectiveness of electrical vs. magnetic absorbers, a study of variations in characteristic height with (1) frequency (2) available materials, (3) distance along the absorber, (4) thickness and any other parameters which may develop. It is expected that an optimum width of absorbers will be found in the sense that we will eventually reach a point of diminishing return with respect to characteristic height as we increase the width. An understanding of such a relationship will be important in obtaining maximum effectiveness with minimum weight.

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D. INLETS AND OUTLETS.

The problem of attenuating reflections from a cavity needs further fundamental understanding. Theoretical and intuitive arguments indicate that, again, electrically lossy materials are most effective in such applications when the material is placed away from metal walls or other metal objects in such cavities, while magnetic materials should be placed in immediate proximity to metal. Thus, the gaseous absorption we have introduced into the exhaust is an electrical loss and is effective because of its volume distribution. In the case of inlets, we have considered lossy egg-crates because of these limitations.

The use of electric absorbers on the spike has given us significant improvements with no attendant interference with airflow. However, a preliminary experiment with magnetic lining on the inlet walls has demonstrated a very significantly larger reduction in return from this source. We plan to pursue this aspect in an attempt to find those features in such a lining which are most effective in producing the desired reduction. Such experiments will be carried out on simplified shapes with the shape gradually becoming more complex as our basic understanding of the phenomena involved increases until we can maximize the performance in the final geometry. Questions which need to be answered include the efficacy of the material as a function of distance as one proceeds into the cavity, the relative value of materials placed on the inlet cylindrical wall as opposed to the back wall of the cavity, and the effect of plugs of various sizes and shapes on the optimum distribution of materials. We would expect, for example, that a plug would enhance the value of materials placed near the inlet to the cavity. We would also plan to investigate the frequency dependence of the importance of backscatter from cavities, as well as the frequency dependence of the reduction obtainable by magnetic absorbers, electric absorbers, or combinations of both.

E. COMPLEX MODELS

It is abundantly evident from the data thus far adduced that optimum AR configurations for portions of the O vehicle cannot be determined alone from either full configuration measurements or measurements on simple shapes or even portions of the actual model. For example, it is evident from much of the work done prior to 1961 that attempts, using the complete model, to discern the usefulness of treatments applied to the fins or the nacelle were obscured by the return from other portions of the model which either alone or in combination had not received optimum treatment. On the other hand, it

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has also been found in a few cases that when AR treatments have been optimized for particular portions from the model and applying various AR treatments, upon re-assembly with the other portions of the model similarly optimized, improvement in the total cross-section pattern were not as great as expected. It is suspected that constructive-destructive interference phenomena can account for these discrepancies. The development of new measuring techniques will be necessary to prove this and permit prediction of such effects. (See Instrumentation section)

It is planned therefor, as noted above, to proceed in our theoretical, experimental and instrumentation program from notional shapes through characteristic shapes of the O vehicle to a fully assembled complex model.

F. MATERIALS

Further significant advances in certain areas appear to be limited at present as much by lack of stability, uniformity and reproducibility of materials as by lack of fundamental understanding. In fact, without adequate control over materials, it can be stated that advances in understanding beyond the present level is highly doubtful. We therefore plan an investigation of the properties of AR materials which will also attempt to provide an understanding of physical and/or chemical features which contribute to uniformity and stability.

We have evidence that mechanical working of carbon loaded materials, for example, can make drastic changes in the AR properties.¹ The possibility that this irreversible process is due to reduction of the carbon to a dust which clumps and possible means to reduce such effects if they exist will be investigated.

G. INSTRUMENTATION

We have been impressed with the fact that most of the major advancements in the program to-date have followed introduction of new and powerful measuring techniques. The introduction of frequency jumping, for example, was followed by the discovery of the importance of trailing edge reflections at vertical polarization. The introduction of the railroad led to many important discoveries at S-band and full scale. Unfortunately, at the lower frequencies where we use an 8th scale model, the resolution available is not capable of providing the same powerful techniques. Alternative techniques are necessary if we are to make further significant advances. One possible technique which we plan to explore would exploit the phase information in the return signal in an attempt to measure the locus or phase center of the reflection. Such information could be very valuable, for example, in determining whether any

¹I.F.I. Technical Memorandum No.1, F.R.Naka, "Measurements of AR Materials at X-Band" (in preparation).

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given chine treatment is less than optimum due to imperfections in the treatment near the chine leading edge or near the chine base. Such measurements, which in some respects are analogous to standing wave measurements on a transmission line, should be capable of development as a variation on the railroad technique and will be pursued now that we have frequency jumping capabilities at L-band and UHF, as well as S-band.

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Most of our residual difficulties in reduction of return occur near broadside where some transverse resolution capability would be of great value. Several cursory attempts have been made in which hair pads have been held in front of the model in suspected areas of strong return. For the most part, these have proved of no value because of inadequate implementation. An organized attack on the development of such techniques could yield a technique directly applicable to this most serious aspect of the remaining problems.